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Working Paper No. 5

## AGRICULTURAL ENERGY CONSERVATION

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A Report to the

Montana Energy Advisory Council

Prepared for

The Montana Energy and MHD Research and Development Institute, Inc.
Butte, Montana

By

The Ecotope Group
Seattle, Washington

MSL AUG 20'80

# 5.0 AGRICULTURE

## 5.1 Introduction: Energy Use in U. S. Agriculture

The production of crops and livestock accounts for only 2.6% of U. S. energy consumption (Heichel, 1976). Maintaining the current rate of food production requires a readily available supply of fossil fuels. However, as Quenton M. West, administrator of USDA's Economic Research Service, notes, "while we have about doubled our farm output in the last 30 years, we have more than quadrupled our fuel consumption--so that farm output per gallon of fuel has declined by half" (Berg,*). The agricultural sector has been granted top priority status in the national allotment of fossil fuels. As a consequence of this status, agriculture's use of energy has been subjected to detailed analysis. Studies by Perelman (1972), Steinhart and Steinhart (1974), Pimental (1973), Commoner (1974), and Rappaport (1971) all conclude that our food production system is in the precarious position of becoming increasingly dependent on decreasingly available resources.

Wilson Clark, California's energy adviser, estimates that U. S. agriculture could reduce energy consumption 20-30% by substituting alternative crop production methods by using machinery more efficiently (Clark, 1975). Unlimited allocation of fossil fuels to the agricultural sector should be viewed as a short-term, stop-gap measure rather than as a final answer. A more appropriate long-range solution is the transition to a food production system which is minimally dependent on fossil fuels.

## 5.2 Energy Use in Montana's Agriculture

Agriculture is Montana's leading industry. Crop and livestock production involve two-thirds of the state's land area, but consumed only 4.4% of the

state's energy (fuel and electricity for fertilizer production in 1974). Thus, the total impact of any conservation measures by the agricultural sector will be minimal. Furthermore, recommendations for energy conservation by Montana's agricultural community are presented with the recognition that Montana's major agricultural activities, cattle grazing and growing dryland wheat, represent two of the most energy-efficient agricultural systems in the U. S. (Fritsch, 1975).

Table 5.1 divides the energy used by the agricultural sector into two basic parts: energy consumed in the production of fertilizer and pesticides and energy consumed directly on the farm. Table 5.2 shows on farm fuel energy consumed. Table 5.3 separates the direct on farm fuel use by thermodynamic quality of the task.

## 5.3 Description of End-Use Energy

### 5.3.1 Analysis of Energy Use

Table 5.4 shows the total quantity of each fuel used for major farm operations. Table 5.5 shows the energy sources consumed in the manufacture of six different types of fertilizers.

### 5.3.2 Efficiencies of Energy Use

Fertilizer-use efficiencies could be improved 25-50% (Wittwer, 1976). The Council for Agricultural Science and Technology (Dean, 1975) suggests that efficiencies of farm machinery could be increased by 10 per cent. Internal combustion vehicle efficiencies can be improved by 25% (Lovins, 1976).

## 5.4 Conservation Strategies

Conservation strategies are outlined with the assumption that Montana's farmers will eventually seek alternatives to fossil-fuel use. Two models of conservation strategies are suggested:

Table 5.1

Energy Used by Montana Agriculture Sector in 1974
(FEA, USDA, 196)

| Task | Btu x $10^{12}$ | % of Total |
|---|---|---|
| ENERGY USE ON FARM | | |
| Field Operations | 5.421 | 23.3 |
| Farm Transport | 5.313 | 22.8 |
| Irrigation | 1.084 | 4.5 |
| Crop Drying | .340 | 1.5 |
| Milking | .299 | 1.3 |
| Waste Disposal | .132 | .6 |
| Misc. | .313 | 1.3 |
| Heating & Cooling | .075 | .3 |
| Sub-Total | 12.987 | 55.6 |
| ENERGY TO PRODUCE FERTILIZERS & PESTICIDES | 10.323 | 44.4 |
| TOTAL | 23.310 | 100.0 |

Table 5.2

On Farm Energy Use in Montana by Fuel in 1974
(FEA, USDA 1976)

| Fuel | Btu x $10^{12}$ |
|---|---|
| | Energy Use on Farm |
| Gasoline | 7.245 |
| Diesel | 3.979 |
| Electricity | 0.882 |
| L. P. Gas | 0.537 |
| Natural Gas | 0.334 |
| TOTAL | 12.987 |

TABLE 5.3

Energy Use by Thermodynamic Quality--1974

(FEA, USDA, 1976)

| Type | | Btu x $10^{12}$ |
|---|---|---|
| Low Heat | Crop Drying | .340 |
| | Space Heating | .017 |
| 2.9% | Milk Cooling | .010 |
| | Ventilation | .007 |
| | Water Heating | .003 |
| | | .370 |
| Electricity | Irrigation | 1.084 |
| | Lighting | .032 |
| 8.8% | Water Supply | .020 |
| | Milking | .007 |
| | | 1.143 |
| Transportation | Field Opern. | 5.421 |
| | Farm Transp. | 5.313 |
| 88.3% | Misc. | .312 |
| | Grain Crops & Livestock | .285 |
| | Waste Disposal | .132 |
| | | 11.460 |

TABLE 5.4

Energy Use by Fuel Type and by Sector for

On-Farm Operations (in $10^{12}$ Btu)

(FEA, USDA, 1976)

| Sector | Gasoline 56% | Diesel 31% | L.P. Gas 4.0% | Elect. 6.6% | Nat. Gas 2.4% | $10^{12}$ Btu | % Total |
|---|---|---|---|---|---|---|---|
| Field Operations | 1.377 | 3.671 | .373 | | | 5.421 | 41.5 |
| Farm Transport | 5.313 | | | | | 5.313 | 41.0 |
| Irrigation | .150 | .295 | .026 | .605 | .008 | 1.084 | 8.6 |
| Crop Drying | | | | .014 | .326 | .340 | 2.6 |
| Milking/ Handling | .277 | .008 | | .014 | | .299 | 2.4 |
| Heating & Cooling | | | .037 | .038 | | .075 | 0.6 |
| Waste Disposal | .128 | .002 | .002 | | | .132 | 1.0 |
| Misc. | | .003 | .099 | .211 | | .313 | 2.4 |
| TOTAL Btu x $10^{12}$ | 7.245 | 3.979 | .537 | .882 | .334 | 12.977 | |

TABLE 5.5

Energy Inputs to Manufacture Fertilizers

| Fertilizer | Natural Gas $1 \times 10^5$ Btu/Therm | | Electricity $3.4 \times 10^3$ Btu/kwh | | Oil Distillate $140 \times 10^3$ Btu/gal | | Oil Residual $1.5 \times 10^5$ Btu/gal | | Total Btu's/lb. |
|---|---|---|---|---|---|---|---|---|---|
| | Therms/ lb | Btu/ lb | Kwh/ lb | Btu/ lb | Gal/ lb | Btu/ lb | Gal/ lb | Btu/ lb | |
| Anhydrous ammonia (82-0-0) | .19 | $19 \times 10^3$ | .03 | $.1 \times 10^3$ | | | .005 | $.75 \times 10^3$ | $19.9 \times 10^3$ |
| Diammonium phosphate (18-46-0) | .06 | $6 \times 10^3$ | .12 | $.41 \times 10^3$ | .003 | $.42 \times 10^3$ | .002 | $.3 \times 10^3$ | $7.13 \times 10^3$ |
| Potash (0-0-60) | .011 | $1.1 \times 10^3$ | .05 | $.17 \times 10^3$ | | | | | $1.27 \times 10^3$ |
| Ammonium nitrate solid (33-0-0) | .1 | $10 \times 10^3$ | .03 | $.1 \times 10^3$ | | | .005 | $.75 \times 10^3$ | $10.9 \times 10^3$ |
| Triple superphosphate (0-46-0) | .015 | $1.5 \times 10^3$ | .09 | $.31 \times 10^3$ | .004 | $.56 \times 10^3$ | | | $2.37 \times 10^3$ |
| 12-12-12 | .04 | $4 \times 10^3$ | .05 | $.17 \times 10^3$ | .001 | $.14 \times 10^3$ | .001 | $.15 \times 10^3$ | $4.46 \times 10^3$ |

Source: Commoner, 1974

The first model focuses on ways to reduce the indirect use of fossil fuels by decreasing the use of synthetic fertilizers and to direct use of fossil fuels by increasing the efficiency of farm machinery and vehicles used for farm transportation.

The second model emphasizes the reduction of both indirect and direct use of fossil fuels by suggesting changes in the mix of crops and livestock produced. Its goal is to achieve energy conservation by dealing directly with the causes rather than the symptoms of increased energy consumption in agriculture. The reasons for the rise of agricultural energy consumption are: increased labor costs, increased farm size, increased use of marginal lands, increased demand for energy-intensive crops, increased population in concert with decreased use of farm labor, decreased crop diversity, decreased soil fertility, and decreased quality of soil structure.

Discussion in the final section examines the fossil-fuel savings achieved by using renewable energy sources.

Since crop production consumes 95% of agricultural energy and livestock production only 5%, conservation strategies are aimed at crop-growing activities.

Table 5.6

FEA-USDA (1976)

Dollar and Energy Values of Montana's Crops and Livestock

| | Value ($1,000) | % of total | Total Btu's Input ($\times 10^9$) | % of total |
|---|---|---|---|---|
| Crops | 929,653 | 71 | 22,629 | 95 |
| Livestock | 381,924 | 29 | 1,182 | 5 |
| TOTAL | 1,311,577 | 100 | 23,811 | 100 |

5.4.1 Conservation Model I

Crop-growing activities which consume major amounts of energy are:

| | |
|---|---|
| Fertilizer production | 44% |
| Field operations | 23% |
| Farm vehicles | 23% |
| Other farm operations | 10% |
| TOTAL | 100% |

5.4.1.1 Decreased Use of Synthetic Fertilizers

Fertilizer and pesticide production consume 44% of the energy used by Montana's agricultural system. Therefore, a variety of strategies for minimizing the need for fertilizers, as well as substituting renewable forms of energy at the production level, could result in substantial energy savings.

The first conservation model suggests the following strategies for reducing the use of synthetic fertilizers:

1. Use of legumes as green manures in summer fallow areas;
2. Use of manures where readily available;
3. Suggested field research to determine the fertilizer-energy savings attributable to:
    a. increased soil and plant-tissue testing
    b. use of synthetic and nonsynthetic nitrifying inhibitors
    c. fertilizer application in spring rather than fall;
    d. substituting biological controls and natural processors for chemical and mechanical manipulation.

5.4.1.1.1 Legumes as green manures

The motivation for using green manures in summer fallow areas is twofold: 1) the soil nitrogen content is increased and 2) saline seep,

the movement of salt deposits to the surface, is controlled. Saline seep was first noticed in the 1960's on acreage which had lain fallow for two or three years due to government subsidies for nonproduction. Currently, Montana may have up to 200,000 acres out of production due to saline seep (Gilles, 1976), and the predictions are for more land to become too saline for agricultural purposes.

Control of saline seep depends on raising annuals or deep-rooted crops on areas where water enters the soil (recharge areas). The roots of first-year alfalfa reach seven feet into the soil where they can absorb excessive water collected during summer fallow periods. This prevents the percolation of water into the saline layer below. The major difficulty in controlling saline seep is that the recharge areas are not easily identifiable. Tom Krall, the agronomist who heads Montana's saline seep research, recommends "growing forages in rotation and using summer fallow sparingly as a weed-control measure or to preserve water during drought," (Gilles, 1976). Some farmers grow grains continually as a saline seep preventative, and their two-year yields closely average those grown using summer fallow (Gilles, 1976).

In addition to preventing saline seep, legumes can reduce the need for synthetic fertilizers. For example, alfalfa, used as green manure to provide N (nitrogen) instead of ammonium nitrate, could save $7.3 \times 10^5$ Btu/acre/year. (See appendix A).

5.4.1.1.2 Manures

Readily collectible manures (see map in biomass section) from dairy cows, feedlot cattle, hogs, or chickens can be applied to fields as a nitrogen source.

The 10 tons of manure produced annually by the average dairy cow, when used as a nitrogen source, could save $11 \times 10^5$ Btu/acre (Pimental, 1973)

in the production of synthetic fertilizer. A beef feeder could save $14.3 \times 10^5$ Btu/acre/year, a 200-pound hog feeder could save $1.2 \times 10^5$ Btu/acre/year, and a laying hen could save $.1 \times 10^5$ Btu/acre/year. (See appendix B).

5.4.1.1.3 Field Testing

Field testing is needed to assess the energy-savings potential of the following:

a. Proper timing and amount of fertilizer application by increased chemical analysis of plant tissues during growth and soil testing prior to fertilizer application.

b. The use of nitrification inhibitors would reduce fertilizer consumption by 25-50% because nitrogen fertilizer is converted by soil microorganisms into unuseable molecular nitrogen gas (Wittwer, 1976). Research is just beginning in the use of nitrification inhibitors: synthetic ("N-serve" Dow) "nitro-pyrine" 2-chloro-6 (trichlormethyl) pyridine and nonsynthetic (chemical from the neem tree of India). The potential energy savings of these agents could be tested.

5.4.1.2 Increased Efficiency of Farm Machinery, Farm Vehicles and Other Farm Operations

Field operations consume 23.3% of Montana's agricultural energy. Field operations include the following: preplanting-cultivation, planting, cultivating, fertilizer and pesticide application and harvesting. Field operations are primarily dependent on diesel fuels (68%) and gasoline (25%) with liquid petroleum gas using the remaining 7%.

Farm vehicles (trucks and cars) consume 22.8% of the agricultural energy, in the form of gasoline. Analysis of the marketing distribution of specific

crops is necessary so that efficient transportation patterns can be determined. This might include greater use of rail transportation. Energy consumption could be reduced by synchronizing the times materials are delivered to the farm with the times that products need to be transported from the farm.

Other farm operations consume 9.5% of the total agricultural energy. These activities include: irrigation, crop drying, milking and milk cooling, heating, cooling and ventilation of animal shelters, and water heating. These activities fall into either the low-heat energy or electrical energy category. Significant energy savings in these categories are best achieved by nonfossil fuel alternatives. (see last section.)

In 1974, irrigation consumed $1.084 \times 10^{12}$ Btu's in fossil fuels to pump $8.49 \times 10^{5}$ acre feet or $12.8 \times 10^{5}$ Btu/acre irrigated. Drip irrigation systems do not require high-pressure application of water. Because water is delivered slowly, less water is lost by evaporation or runoff. Both the water and energy used by a drip system is approximately 50% of conventional systems (Wittwer, 1976). The use of gravity flow sprinkler systems has already saved substantial amounts of power in areas of Montana where sufficient fall exists to generate needed pressure. Five such projects in Ravalli County, Montana, have substantially repaid their cost by irrigating several thousand acres more efficiently and with almost no power input (Bjergo 1976).

Where sufficient pressure exists in each pipeline to require pressure reducers, the insertion of small turbines which would simultaneously generate electricity may be able to harness this extra pressure for nearby use. Many ranches also use hydraulic rams to pump water to high points.

Energy for heating or cooling animal shelters can be reduced or even eliminated by appropriate insulation. (See commercial and residential sections for Btu/square foot savings using a variety of insulation strategies.)

The first conservation model suggests the following tactics for reducing the use of fossil fuels.

5.4.1.2.1 Improved operation, maintenance and design of farm equipment could average a $0.57 \times 10^5$ Btu/acre/year saving in Montana. (See appendix A). The Council for Agricultural Science and Technology (Dean, 1975) states that a 10% reduction in fuel use could be achieved by using machinery precisely scaled to the job, running at efficient speeds, and adhering to proper maintenance routines. If gasoline consumption could be reduced by 10%, this would result in an average savings of $.56 \times 10^5$ Btu/acre/year. A 25% reduction would save $1.4 \times 10^5$ Btu/acre/year (see appendix A).

Field testing is needed to assess the energy-savings potential of tactics 2 through 4.

5.4.1.2.2 Appropriate coupling of machinery, i.e., combining several operations in one trip over the field.

5.4.1.2.3 Spring rather than fall plowing when the soil is more easily worked due to the loosening action of winter frost and moisture.

5.4.1.2.4 The energy tradeoffs of reduced till or no till with increased herbicide use for wheat production. Reduced tillage is estimated to reduce fuel consumption by 20-30% (Ronald, 1975), but the additional energy consumption due to the accompanying increased herbicide useage is unknown.

5.4.2 Conservation Model II

The second conservation model stresses the importance of interacting conservation strategies. The goal is not merely to reduce energy consumption by the agricultural sector, but to create ecologically stable and (as nearly as possible) energy self-sufficient farms. Energy self-sufficiency is achieved by minimizing the amount of energy used on farms in the form of fertilizers, pesticides, and fuels.

A description of Montana's major farming patterns is followed by suggestions for increasing their ecological stability and energy self-sufficiency.

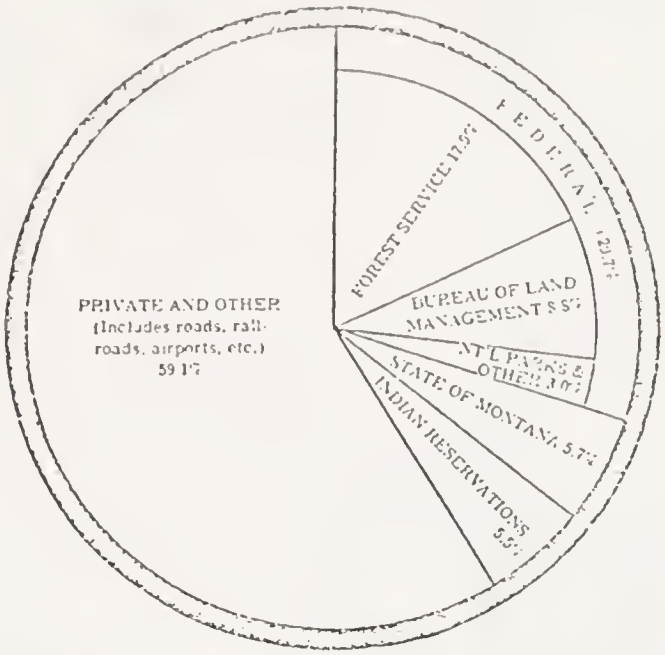
In 1974, while 68 per cent of the farm land was used for pasture or range, livestock accounted for only 29% of the agricultural cash receipts. Harvested cropland represents 13.5% of Montana's land in farms, with an additional 10.2% of the farm land in summer fallow. (See Figure 3.1.) In 1974, harvested crops accounted for 71% of the agricultural cash receipts (USDA, FEA, 1976). More crop acreage is used to grow winter wheat than any other single crop. Grown on 4% of the land, winter wheat alone brought in one-fourth of the total agricultural cash receipts (calculated from USDA, FEA, 1976).

The motivation for growing wheat is high, but concerns for the consequences of continued dryland practices are being voiced. Some feel that summer fallowing and monocultural practices will eventually force abandonment of the land due to increased salinity (Galles, 1976). Montana agronomist Krall states that "...the control of saline seep will require change. This change is going to involve machinery, engineering, economics, agronomy, animals and people." He advocates the growth of forage crops on summer fallow lands. One of the hallmarks of a closed and stable ecosystem is the cycling of nutrients between plants and animals. Forage crops transported to small community feedlots would ultimately provide readily collectible manure that could be returned to crop land -- reducing the need for synthetic fertilizers. Seventy per cent of the

Figure 5.1

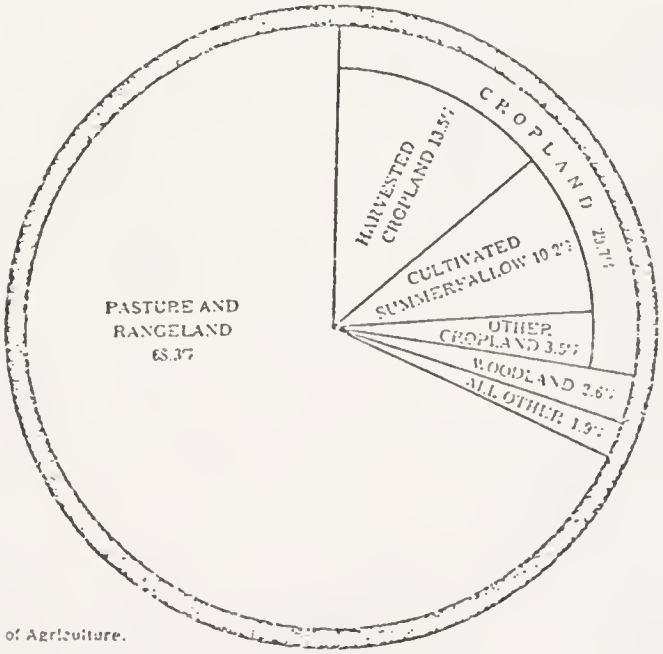
MONTANA LAND AREA AND LAND IN FARMS

MONTANA LAND AREA (93.2 Million Acres)
Ownership as Percentage of Total




Source: "Public Land Statistics, 1969" and Montana Department of Lands.

LAND IN FARMS (62.9 Million Acres)
Utilization as Percentage of Total




Source: 1969 Census of Agriculture.

nitrogen content of alfalfa is retained in manure (calculated from Bear, 1965).

Cultivation of forage crops on the average 2500-acre farm calls for either a complete retooling of large-scale forage equipment or preferably smaller farms that would use haying and chopping equipment scaled to existing tractor sizes (Gilles, 1976). Another factor favoring smaller farm size is that the maximum cost-saving production efficiency of wheat farming is generally reached at less than 1,000 acres (Kotz, 1976).

In addition to the cycling of nutrients between plants and animals, another important characteristic of natural ecosystems is diversity of species. This diversity reduces the threat of attack from pests and diseases and the need for pesticides. Encouraging breeding of animals which can forage year-round would reduce the need to harvest forage. The non-exotic beef breeds, sheep, and cattalo (beef/buffalo cross) forage well. Sheep numbers are down; yet if predator problems can be resolved with proper management, this system will provide a double dividend of meat and recyclable clothing while utilizing substandard grazing lands. Saline and drought-tolerant plants include sweet clover (Hallowell, 1957), safflower, barley, grain sorghum (Martin, 1957), "cowpeas and horse beans," and dryland silage corn (Gilles, 1976). Forage crops can be fed to a variety of livestock.

The development of economically viable methods for using nonforage crops needs to be begun; for example, safflower-oil production requires the construction of local refineries.

In general, smaller farms which grow a mixture of livestock and crops adapted to the soil and climactic conditions for each of Montana's agricultural regions, as well as the development of local industries to use nonforage crops, represent the best potential for ecologically sound and energy self-sufficient farms.

Table 5.7.--Implementation Strategies for Conservation in Agriculture

| | |
|---|---|
| Immediate implementation by individual farms: 1980 | 10% increase efficiency of farm machinery |
| | use of reduced till or no till where possible |
| | 10-25% increased efficiency of farm transportation vehicles |
| | use of legumes as cover crops |
| | use of manures where readily collectible |
| | increased insulation of animal shelters |
| | supplemental to complete solar water heating |
| Intermediate implementation by groups of farmers: 1990 | diversified crops & livestock on a regional basis |
| | reduced farm size |
| | minimized use of synthetic fertilizers by using cover crops, manure, nitrifying inhibitors |
| | minimized use of synthetic pesticides by growing diversified crops and biological weed and insect control |
| | supplemental to complete wind generation of electricity |
| | supplemental to complete heating and ventilation with solar energy or biogas |
| | supplemental to complete grain drying with solar energy |
| | supplemental to complete fueling of machinery with alcohol or other biomass conversion products |
| Long-range implementation by groups of farmers: 2000 | Energy self-sufficient farming units |

The final section lists ways in which renewable energy forms can be used in lieu of fossil fuels.

Table 5.7 summarizes immediate, intermediate, or long-range strategies for implementing conservation tactics and applying renewable energy sources in agriculture.

5.4.3 Renewable Energy Strategies

The low energy and electrical consuming farm activities lend themselves to wind, solar, geothermal, and biogas applications. Hot springs are an important source of winter stock water in some areas and are used to heat some structures. Specific Btu savings and Btu costs are described more specifically in wind, solar and biomass sections. Table 5.8 merely outlines applications of renewable energy sources to agricultural activities.

5.4.3.1 Using Renewable Energy Sources to Produce Fertilizer

Natural gas is used as a hydrogen source and often as an energy source in the production of anhydrous ammonia. Ammonia production can be independent of fossil fuels if the following criteria are met:

1) atmospheric nitrogen combines with hydrogen from the hydrolysis of water rather than hydrogen from natural gas, and
2) wind-powered electricity provides the heat of reaction, rather than natural gas or residual oil.

Such a process is described by Tunis Wentink, Jr. (1976). He suggests that a windmill complex of 59 MW installed capacity would be necessary to hydrolyze enough water to produce 100 tons of ammonia a day. An additional .714 MW/hr/ton are needed to combine the hydrogen with atmospheric nitrogen in the process.

$$3H_2 + N_2 \rightarrow 2NH_3$$

Montana's present rate of nitrogen consumption requires four of these plants. They would generate an energy savings of $5.6 \times 10^5$ Btu/acre/year. This is about half of the energy currently used to produce all the fertilizers used annually in Montana. (See wind section for cost analysis of windmill construction.)

Table 5.8.--Estimates of Local Energy Requirements for a Small Community

| Energy use | Annual energy (kw hr) Equivalent | Timing Requirements | Probable Energy Source | Basis of Estimation | Sour |
|---|---|---|---|---|---|
| Cooking | 400/family | day, precise | Or, S | 1-1.5 kw stove used 1 hour/day | a |
| Domestic water | 50/family | random | W, Wa, Or | 150 gallons/day | b |
| Refrigeration | 200/family | random | W, Wa, S, Or | 1/2 kw unit run 1 hour/day | c |
| Water heating | 3,500/family | random | S or W, G | 50 gallons/day | b |
| Lighting, domestic power | 850/family | night and day, precise | W, Wa, Or | 5 100-watt lights used 4 hours/day 1/3 kwh misc. items | c |
| Water distillation | 130/family | day, random | S, Or | 5 gal/day; solar collector $5m^2$ giving 3/4 kw over 24 hours | a |
| Solar house heat | 4,100-15,000 | day & night, precise | S, Or, G | 7.3-10 kw avg. heat requirement; 60-750 kw hour heat storage | d |
| Irrigation | 300/acre feet | random | W,Wa,S,or, G | Geothermal can be used for greenhouse operations | a |
| Cultivation Seeding | 5,600/25 hp/75 Hours | variable | Or, W, S | 25 hp tractor used 75 hours/year | b |
| Mechanical grinding, food mixing, rudder chopping | 50/family | random | W, Wa, Or | average of 1/2 family hour including animals | a |
| Threshing | 50/family | random | Or, W | 4 tons/family/year | a |
| Misc. small power | 100/family | day & night, precise | W, Wa, Or | 5 kw total power | a |
| Transportation | 7,500 vehicles, 25 hp/100 hrs USE | variable | Or, W | 25 hp vehicle used 100 hours/year | |

Legend: 1 family=4 people Or=organic fuels W=wind S=solar Wa=water G=Geothermal

Sources: a) Golding & Thacker, Utilization of Wind: b) Edwin Anderson, Domestic Water Supply & Sewage Disposal Guide; c) Henry Clews, Electric Power from the Wi
d) Daniels, Direct Use of the Sun's Energy

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APPENDIX A

Calculations

Legumes

Alfalfa contains 100 lb N/acre (calculated from Bear, 1965)

$10.9 \times 10^3$ Btu/lb to produce ammonium nitrate (Commoner, 1974)

$3.60 \times 10^5$ Btu/acre for legume seedlings (Pimental, 1973)

100 lb. N x $10.9 \times 10^3$ Btu/lb. = $10.9 \times 10^5$ Btu equivalent savings

$- \underline{3.6 \times 10^5}$ to grow seedlings

$7.3 \times 10^5$ Btu/acre/year net savings

Manures

The 10T of manure produced per year by the average dairy cow contain

193 lb. N x $10.9 \times 10^3$ Btu/lb of ammonium nitrate = $2.1 \times 10^6$ Btu

79.2 lb. $P_2)_5$ x $2.37 \times 10^3$ Btu/lb - $0.187 \times 10^6$ Btu

153 lb. of $K_2O$ x $1.27 \times 10^3$ - $0.194 \times 10^6$ Btu

Total of these 3 is $2.48 \times 10^6$ Btu/acre equivalent in manure.

11 gallons of gasoline x $125 \times 10^3$ Btu/gal - $1.37 \times 10^6$ Btu are required to haul and spread 10 tons of manure over a 1/2 to 1 mile radius (Pimental, 1973).

Thus $(2.48 - 1.37) \times 10^6 = 11 \times 10^5$ Btu/acre.

(figures calculated from FEA USDA, 1976)

Field operations consume $5.421 \times 10^{12}$ Btu's on $9{,}429 \times 10^3$ acres

$$10\% (5.421 \times 10^{12}) = \frac{5.421 \times 10^{11} \text{ Btu}}{9429 \times 10^3 \text{ acres}} = .577 \times 10^5 \text{ Btu/acre}$$

Annual gasoline consumption = $5.313 \times 10^{12}$ Btu on $9429 \times 10^3$ acres

$$10\% = (5.313 \times 10^{12}) = \frac{5.313 \times 10^{11} \text{ Btu}}{9429 \times 10^3 \text{ acres}} = .56 \times 10^5 \text{ Btu/acre}$$

$$25\% = (5.313 \times 10^{12}) = \frac{1.33 \times 10^{12} \text{ Btu}}{9429 \times 10^3 \text{ acres}} = 1.4 \times 10^5 \text{ Btu/acre}$$

$$\text{Annual Energy Consumption} = \frac{22.6 \times 10^{12} \text{ Btu/acre}}{9429 \times 10^3 \text{ acres}} = 24 \times 10^5 \text{ Btu/acre}$$

APPENDIX B

Fertilizer Energy Equivalent of Various Manures

| | Manure tons/yr | Energy required to produce equivalent amounts of fertilizer N | P | K | Gross Btu equivalent to synthesize fertilizer | (minus) energy to haul | net Btu/acre |
|---|---|---|---|---|---|---|---|
| 1,000-pound beef feeder | 11 | $10.9 \times 10^3$ Btu / 124 lb. | $2.37 \times 10^3$ Btu / 92 lb. | $1.27 \times 10^3$ Btu / 110 lb. | | | |
| | | $13.5 \times 10^5$ Btu/yr | $2.2 \times 10^5$ Btu/yr | $1.4 \times 10^5$ Btu/yr | $17.1 \times 10^5$ | $15 \times 10^5$ | $2.1 \times 10^5$ |
| | | | | | | *$2.8 \times 10^5$ | 14.3 |
| 200-pound hog feeder | 2.4 | 32.8 lb. | 24 lb. | 26.3 lb. | | | |
| | | $3.58 \times 10^5$ Btu/yr | $.59 \times 10^5$ Btu/yr | $.33 \times 10^5$ Btu/yr | $4.5 \times 10^5$ | $3.3 \times 10^5$ | $1.2 \times 10^5$ |
| Laying hen | .038 | 1.06 lb. | 0.95 lb. | 0.55 lb. | | | |
| | | $0.12 \times 10^5$ Btu/yr | $.02 \times 10^5$ Btu/yr | $.01 \times 10^5$ Btu/yr | $.5 \times 10^5$ | $.05 \times 10^5$ | $.1 \times 10^5$ |

*This lower hauling energy is the result of dry-climate feedlots where most of the moisture has been evaporated.

Source: N, P, K, figures from Hermanson, 1974

# APPENDIX C

In 1973, Montana used $4.27 \times 10^6$ pounds of anhydrous ammonia. Since ammonia is needed to produce ammonium nitrate and ammonium sulphate, and urea is also produced in ammonia plants, total nitrogen fertilizer use is also considered at $26.6 \times 10^7$ pounds in 1974.

A 100-ton 1-day plant produces $7.3 \times 10^7$ pounds ammonia/year.

Thus, one plant could meet anhydrous ammonia needs directly and 3 additional plants could provide the ammonia for other nitrogen fertilizers.

Equivalent amounts of anhydrous ammonia using present fossil fuel-based production techniques consumes $26.6 \times 10^7$ pounds $\times$ $19.9 \times 10^3$ Btu/lb. $= 5.29 \times 10^{12}$ Btu/year.

This savings averaged over $9429 \times 10^3$ acres =

$$\frac{5.29 \times 10^{12} \text{ Btu/year}}{9429 \times 10^6 \text{ acres}} = 5.6 \times 10^5 \text{ Btu/acre/year}$$

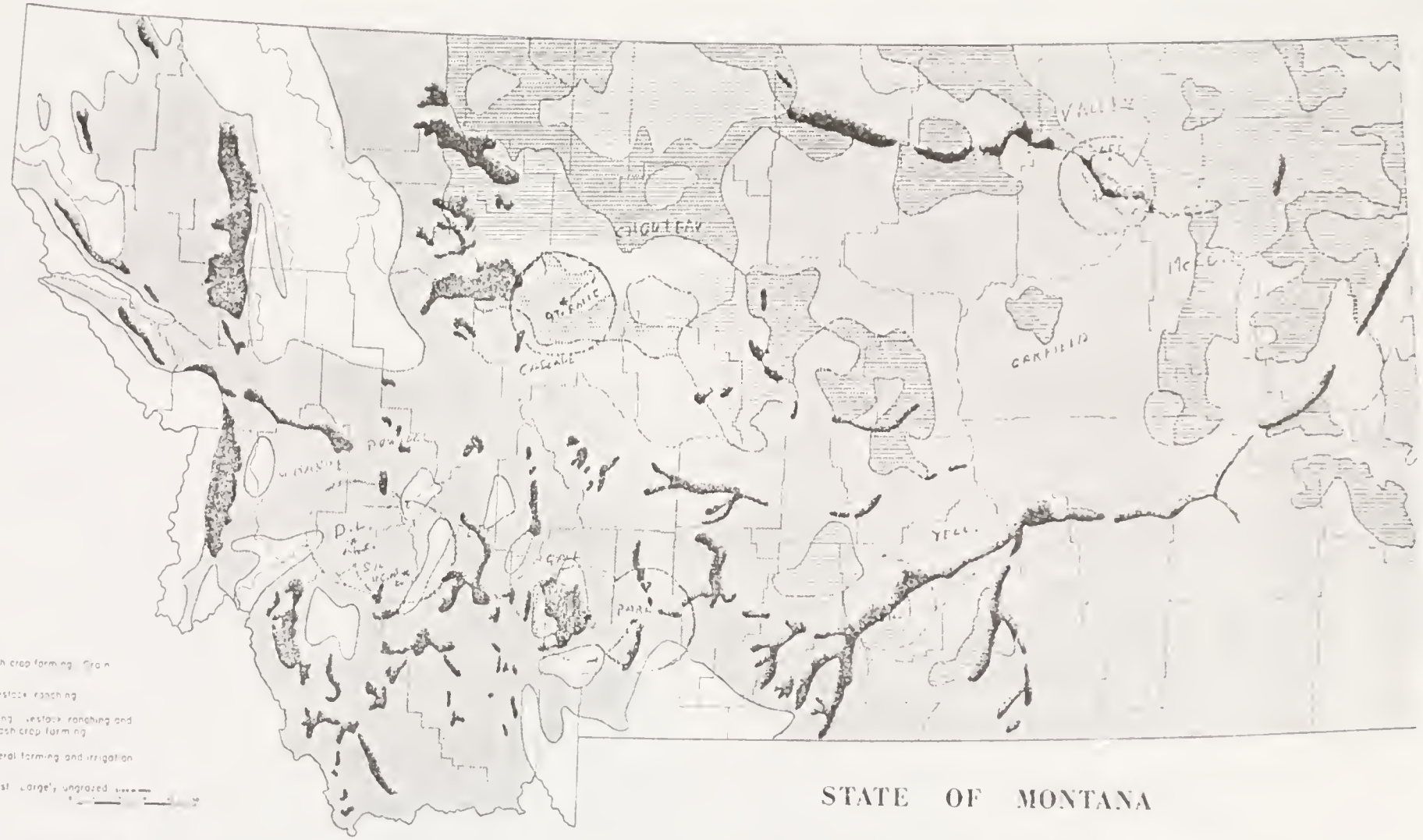
APPENDIX D

COMMERCIAL FERTILIZER CONSUMPTION

By Primary Nutrients and Fertilizer Materials, 1968-1973[1]

| PRIMARY NUTRIENTS | 1968 | 1969 | 1970 | 1971 | 1972 | 1973 |
|---|---|---|---|---|---|---|
| Nitrogen | 30,429 | 36,507 | 36.786 | 41,207 | 43,913 | 52,840 |
| Available $P_2O_3$ | 44,188 | 48,221 | 49,775 | 56,834 | 50,154 | 62,346 |
| $K_2O$ | 1,688 | 1,220 | 1,572 | 1,262 | 2,504 | 2,983 |
| TOTAL NUTRIENTS[2] | 76,305 | 85,948 | 88,113 | 99,304 | 96,571 | 118,169 |
| FERTILIZER MATERIALS | | | | | | |
| NITROGEN MATERIALS: | | | | | | |
| Anhydrous Ammonia | 1,996 | 1,538 | 2,390 | 1,705 | 2,069 | 2,137 |
| Aqua Ammonia | 441 | 571 | 341 | 125 | 153 | 247 |
| Ammonium Nitrate | 14,163 | 27,570 | 26,951 | 35,988 | 60,936 | 73,656 |
| Ammonium Sulphate | 1,636 | 1,766 | 2,232 | 1,794 | 3,090 | 6,146 |
| Nitrogen Solution | 4,994 | 4,523 | 4,536 | 4,352 | 3,213 | 2,781 |
| Urea | 299 | 264 | 249 | 1,523 | 239 | 46 |
| Other | 1 | 45 | 68 | 28 | 6 | 79 |
| PHOSPHATE MATERIALS: | | | | | | |
| Phosphate Rock | 19 | 5 | 2 | 14 | 0 | 0 |
| Superphosphate--over 22% | 20,454 | 16,496 | 19,358 | 14,958 | 11,414 | 11,230 |
| Ammonium Phosphate | 60,565 | 52,166 | 45,589 | 38,455 | 33,748 | 39,797 |
| Other | 4,676 | 5,177 | 4,440 | 2,087 | 2,212 | 3,737 |
| POTASH MATERIALS: | | | | | | |
| Chloride 50-62% | 1,126 | 1,464 | 1,913 | 1,602 | 3,878 | 4,865 |
| Other | 50 | 102 | 5 | 8 | 0 | 0 |
| NATURAL ORGANIC | 225 | 246 | 195 | 292 | 166 | 150 |
| SECONDARY AND MICRONUTRIENTS: | | | | | | |
| Gypsum | 1,179 | 1,172 | 464 | 889 | 215 | 463 |
| Other | 110 | 216 | 68 | 60 | 20 | 23 |
| MIXTURES | 55,654 | 73,040 | 77,650 | 99,057 | 81,654 | 100,572 |
| TOTAL MATERIALS | 167,538 | 186,361 | 186,451 | 202,947 | 203,013 | 245,929 |

[1] Year ending June 30.
[2] Data for some years may not add due to rounding.


KEY
Cash crop farming - Grain
Livestock ranching
Mixed livestock ranching and cash crop farming
General farming and irrigation
Forest - largely ungrazed
SOURCES
USDA, Farm Adjustments in Montana, 1940
USDI, Bureau of Reclamation, Irrigation Data for the Columbia and Missouri River Basins

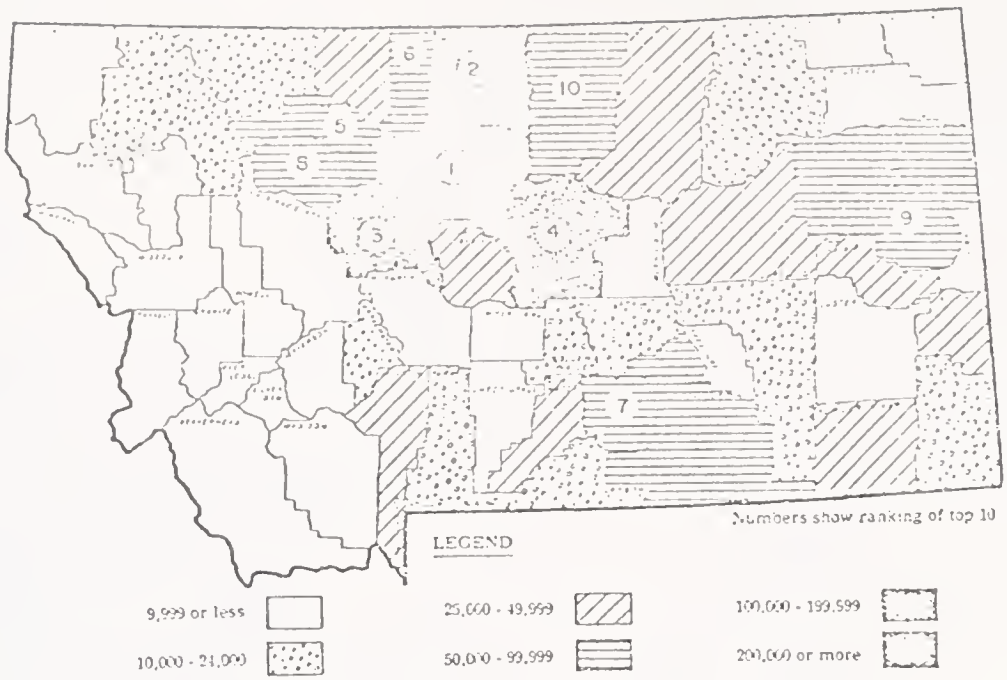
STATE OF MONTANA

# TYPES OF FARMING

APPENDIX E

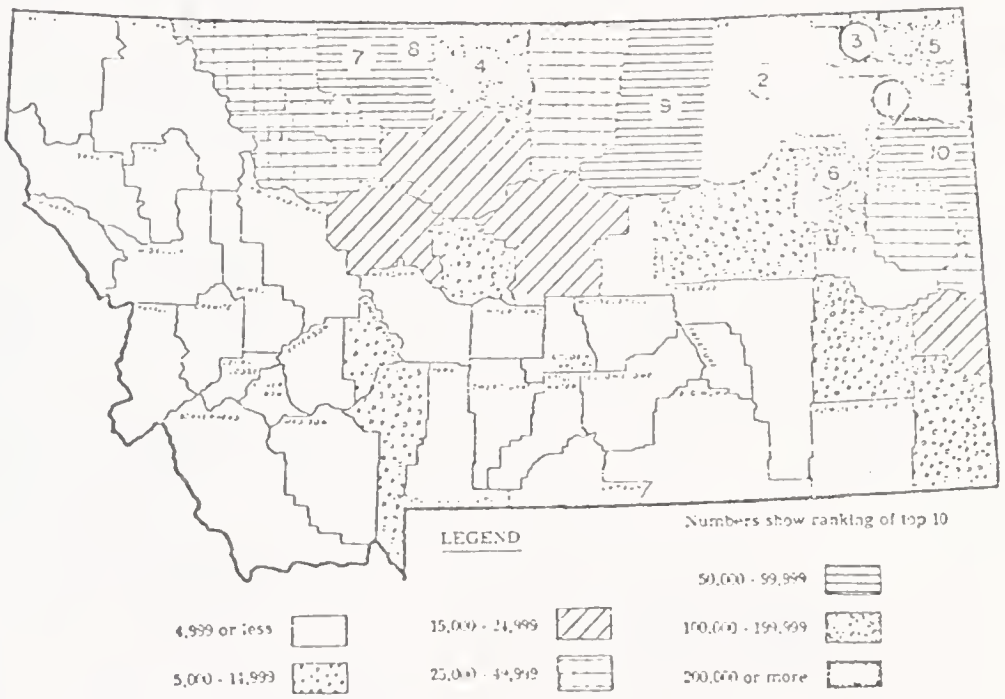
WINTER WHEAT

Acreage Harvested, 1973




SPRING WHEAT OTHER THAN DURUM

Acreage Harvested, 1973

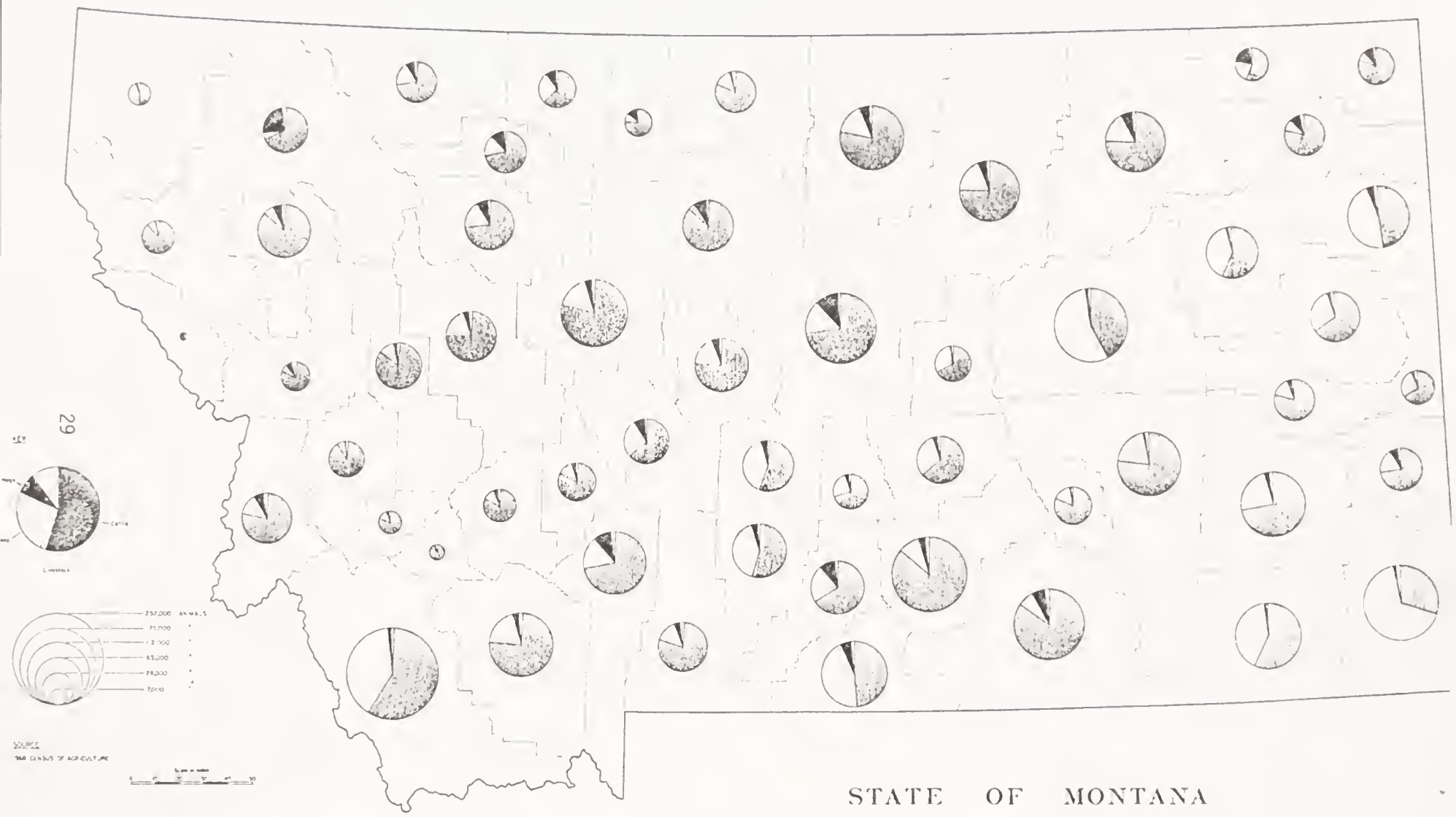



APPENDIX F

STATE OF MONTANA

# LAND IN FARMS

As A Percent Of Total County Land

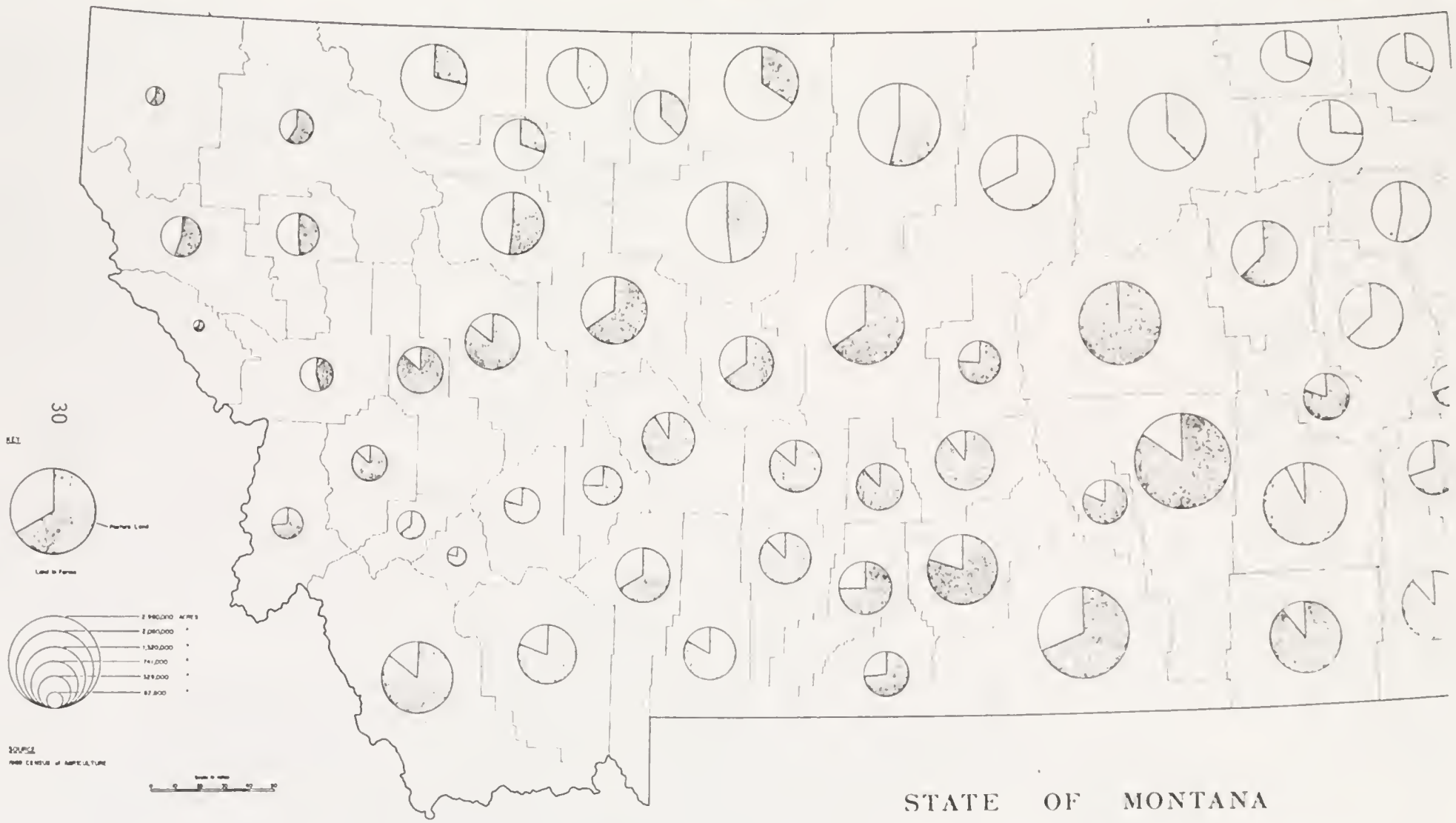


STATE OF MONTANA

# CATTLE, SHEEP & HOGS

As A Percent Of All Livestock

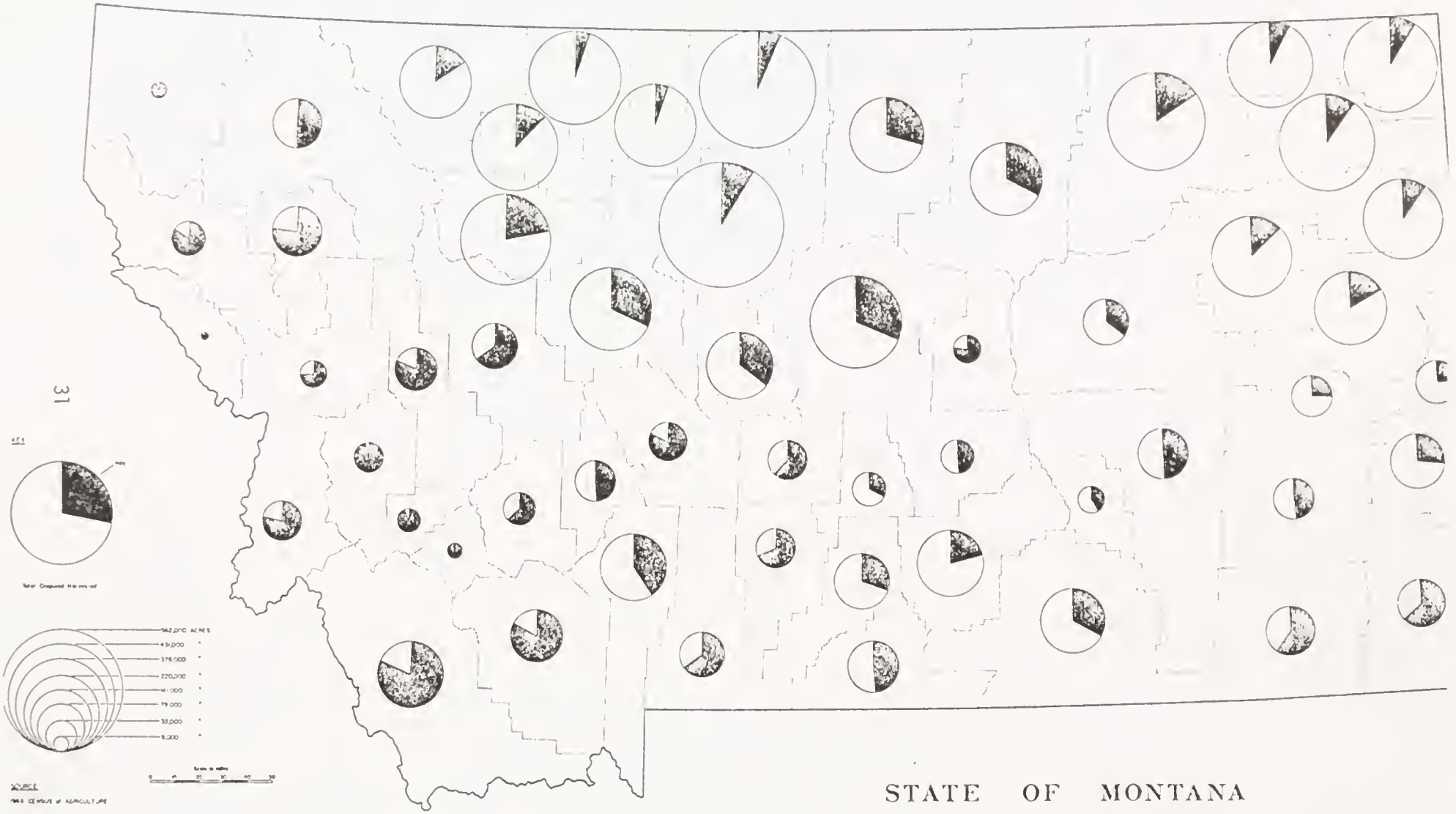
APPENDIX H




STATE OF MONTANA

# TOTAL PASTURE LAND

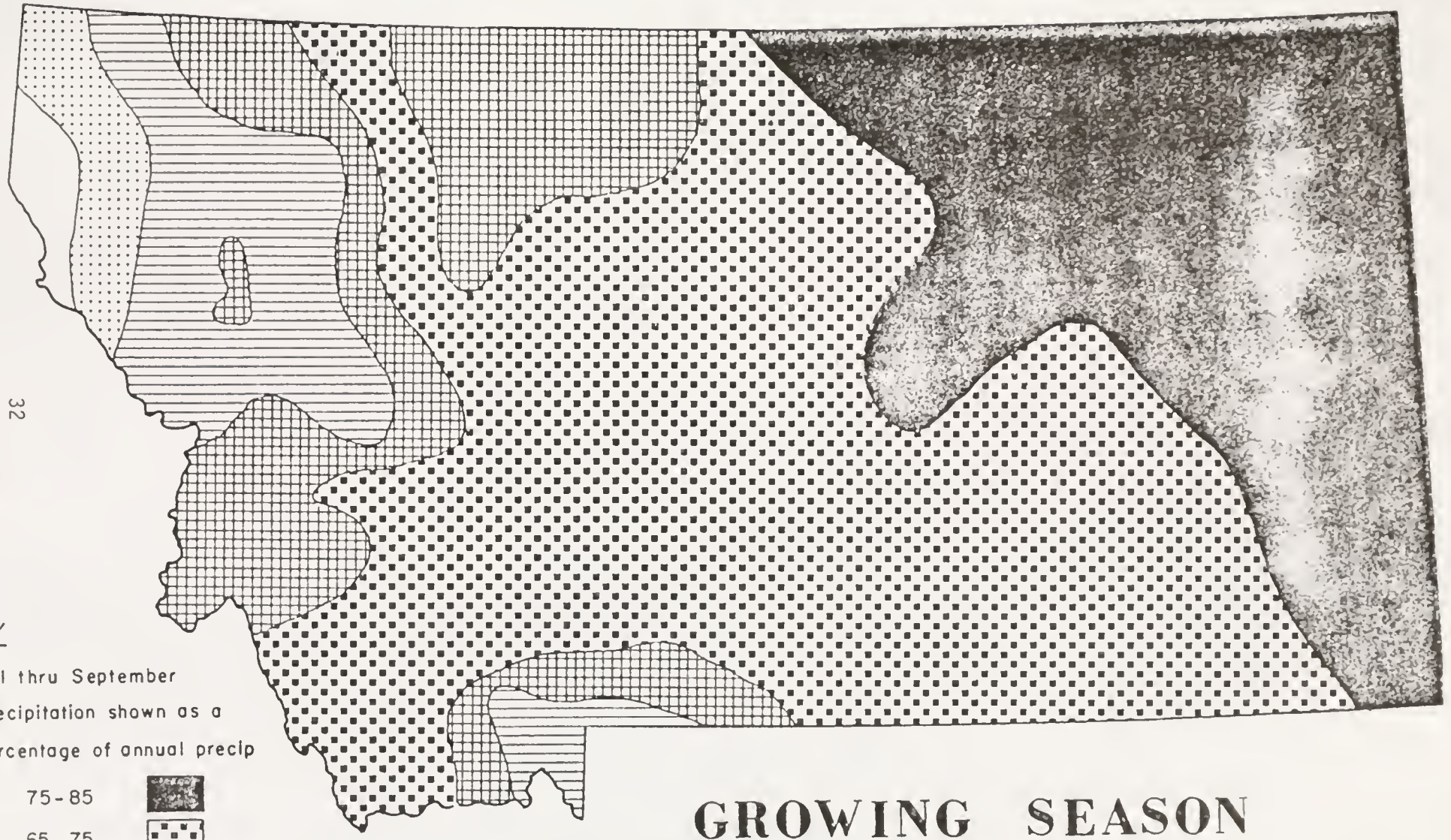
As A Percent Of Land In Farms



STATE OF MONTANA

# HAY HARVESTED

As A Percent Of Cropland Harvested



KEY

April thru September precipitation shown as a percentage of annual precip

- 75-85
- 65-75
- 55-65
- 45-55
- 35-45
- 25-35

SOURCE

USDA, Climate and Man

USDC, Bull. W and Supp. 11-20.

# GROWING SEASON PRECIPITATION

APPENDIX K